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Disruptive Environmental Technologies of High Population Impact Aimed at the Disposal of Recyclable Materials[1]

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Abstract

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1. Introduction

Technology has been gaining more and more space in everyone's lives over the years, especially in large cities. Few people do not resort to applications or functionalities on their smartphones for some daily activity, whether to order food, calling a car, or even quantifying the mileage and time of morning rides.

Institutionally, companies have also become dependent on technology, with their integrated databases of high scalability and interoperability stored in VPS or clouds, whose information is necessary for any service. In short, this database ends up being the company's most precious asset because, without it,

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revenue and profits cannot be accessed; for this reason, the servers are protected by various firewalls, fixed IP, and backup routines to preserve such information.

In this way, the rise of capitalism, increased industrialization, increase in consumption, including technologies, combined with the purposeful low durability of this type of product, generates a large amount of waste, resulting in the current discussions on sustainable development.

“Sustainability”, or “Sustainable Development”, is basically the balance between attitudes towards social and economic development based on environmental preservation measures. It radically changes the decision-making process by government officials, entrepreneurs, consumers, and workers who, for a long time, took only economic criteria into account. However, currently, they also need to consider social and environmental aspects.

Therefore, the sustainability theme began to be considered relevant for business in recent years, due to the possibility of a more fluid production process, with no obstacles, from the raw material to the final consumer, including the reverse movement of this process, which comprises the return of leftovers after consumption [1].

Thus, it is important to establish a historical context on this theme, emphasizing the concepts of sustainability and environmental preservation in the Capitalist System. In this way, initially, it will be approached the starting point of these discussions and the development of the first technologies focused on a greener perspective, giving some examples of technologies based on which Cardozo and Murarolli [2] discussed in their text “Green Information Technology: Technological Sustainability. The Advancement of Technology in Relation to the Environment: Technology and Sustainability”.

Subsequently, it will be discussed how technologies are used as “green patents”, which are instruments that allow industries to include more appropriate and alternative methods into their production processes, as they are less polluting, mitigating environmental degradation and bringing competitive advantages to these companies. Specifically, at this moment, it is established a dialogue with Santos *et al.* [3], based on the text “A model of management information system: competitive advantage in the process of reverse logistics of cooking oil”, which deals with the application of a Management Information System (MIS), as an information technology tool for reverse logistics of residual vegetable oil from industries, using a franchise of a fast-food chain in São Paulo, Brazil, as a case study.

Finally, the third text will address the invention and utilization patents developed in Brazil directly related to alternatives for the disposal, reuse, and/or recycling of products for non-environmental degradation. The case study by Silva *et al*. [4] addresses the Brazilian civil construction sector, which concentrates more waste disposed per inhabitant per year in comparison with domestic waste, as argued in their study entitled “Mapping of technologies associated with the reuse of solid waste and recycling of used materials in the Brazilian civil construction sector”, which also shows data that contribute to understanding how we are in terms of technological measures to be used in companies directly linked to the recycling industry and the reuse of solid waste.

In the second chapter, it will be addressed, according to Christensen [5], the concept of disruptive technologies, which can be considered innovations in products, services, or processes, which seek to be alternatives to technologies in force and are also focused on another type of consumer. In short, for this author, disruptive innovation is intended to cause changes in social practices and the ways of living, working, and relating, causing a disruption in standard models related to the field of consumption and business.

Moreover, two technological tools, which can be considered disruptive, will be presented, due to their high educational content and great ability to change their users' thought and consumption habits. These tools cause an imaginary disruption of high population impact since they are aimed at the masses and can cause permanent changes in the consumer's subconscious.

Thinking about it, why do we not use technology as an ally to more sustainable practices? This is intended to be reflected in our work, which sought to understand the current role of technologies and how they can contribute to changing society's thoughts and habits.

2. Materials and Methods

This study was performed using a qualitative method, as it "involves a universe of meanings, reasons, aspirations, beliefs, values, and attitudes, which corresponds to a deeper space of relationships, processes, and phenomena that cannot be operationalization of variables" [6].

In addition, it is based on a theoretical review of articles found from a survey on the Google Scholar platform, between March 20th and 21st, 2020, using the following keyword combinations: (1) Information Technology and Recycling and (2) Disruptive Technology and Recycling. The survey was carried out in order to find papers most appropriate for the research subject, published by the Brazilian and international scientific academic community in journals and other means of dissemination, such as annals of events.

The main studies on Information Technology found in the review were conducted by (1) Cardozo and Murarolli [2], which deals with green information technologies and cites Cloud Computing and Virtualization as a representation of this type of innovation; (2) Santos *et al*. [3], which proposes a discussion on the disposal of effluents in water resources; and (3) Silva *et al*. [4], which addresses green patents and their main aspects.

The following studies on disruptive innovations and technologies were also found: Theis and Schreiber [7], Gilioli [8], Carvalho, Pereira, and Assis [9], among others, which are based on the ideas defended by

Christensen [5], main researcher on “disruptive technologies”.

Finally, a case study of two green patent technologies (Intelligent Garbage Can and Recycling Scoreboard) was also performed. The method used for the Recycling Scoreboard comprised PHP programming language, Mysql database, and a video already edited, rendered, and containing the information to be shown on the screen (Figure 7). The Intelligent Garbage Can comprised development in C++ on the printed circuit board, PHP, Html, Java Scripts, and Mysql database. Regarding the server environment, Java servlet (UDP), fixed IP, VPS virtualization environment, and insertion in the MySQL database were used.

3. Green Information Technology and Environmental Concern: Reuse of Materials and Recycling in Industry

According to Cardozo and Murarolli [2], a commission for the establishment of developmental and environmental measures for all countries in the world was created, in a conference of the United Nations Organization, in the 1980s. During this event, there was a discussion on issues related to environmental impacts generated by the excessive exploitation of resources, as well as on measures to mitigate these impacts, such as reduction of energy consumption, environmental preservation, and recycling.

From 1987, the Our Common Future Report, also called the Brundtland Report, was instituted, bringing the need for a real change to support global progress (sustainable development). Also, according to its authors, this document criticized the measures adopted by central capitalist countries. These measures, based on this report, were unlikely to be applied in peripheral capitalist countries.

In 2005, the term “Green Information Technology” was implemented, which, according to Cardozo and Murarolli [2], is quite recent but has gained considerable space in discussion and implementation of alternatives such as virtual storage (e.g. clouds). According to such authors, companies realized the importance of their virtual assets, thus increasing investment in Information Technologies (IT).

From then on, it has been strengthening, since globalization is intrinsic to the development of information technologies, and the continuous and permanent transmission of information is essential. Some developed technologies are directly related to Green IT such as cloud computing (1) and virtualization (2).

Cloud computing consists of a virtual storage space (in clouds), in order to eliminate the use of physical storage memory. Cardozo and Murarolli [2] argue this method has been adopted by several companies that want to save time and costs in the maintenance of equipment. However, in the beginning, it generated suspicion because of the idea that the storage could be lost, deleted, or invaded, no longer remaining in the company’s sole possession.

Therefore, companies currently hire servers with known security certificates and there are four possible types of cloud computing: public, community, hybrid, and private clouds [2].

Public clouds, still according to the authors, are a standard model of cloud computing, free of charge or pay-per-usage. Community clouds are accessed by a specific group with common interests. The hybrid ones are two or more clouds, which offer the benefits of the other clouds in a single one. Finally, private clouds are storage services aimed only at a specific organization or company.

In a dialogue with Dâmaso [10], Cardozo and Murarolli [2] claim that it is possible to exemplify companies that currently use this storage method, such as Google Drive, Dropbox, SkyDrive, and iCloud. All these companies offer storage options, obviously with specific differentials, according to the interests of their customers. Furthermore, cloud computing is an alternative for reducing CO_2 emissions, energy consumption, and waste generation; for this reason, they are considered as a green technological alternative.

To understand the concept of virtualization, intertwined with this notion of clouds, it is necessary to distinguish the real, as something palpable, the material, and what simulates what is real, i.e., the virtual. According to Cardozo and Murarolli [2], virtualization is a "virtual environment that seeks to imitate a real environment, being able, in this way, to use all systems and programs, even if they are not installed in the virtual environment". In other words, virtualization proposes to optimize the use of physical equipment as much as possible. Thus, there are three manners of understanding virtualization: hardware virtualization, presentation virtualization, and apps virtualization.

The hardware virtualization is defined by the use of several operating systems on a single machine, whose data of their components are "copied" through softwares to be read and used by the different operating systems.

The presentation virtualization consists of accessing a computational environment without the need for physical contact with it. Therefore, this type of virtualization is similar to remote access; however, it can be accessed by several users at the same time. Its advantage is the possibility of access, from any location, using the operating system's tools, without the need to install them on a physical computer.

Finally, apps virtualization is an important tool to avoid software incompatibility on certain operating systems. Thus, by installing an application on a remote desktop, the user can access it from any area, using any operating system.

Cardozo and Murarolli [2] emphasize this form of technology is important in terms of saving energy consumption, as well as physical space, generating no waste from equipment acquired and used in excess. The standards by which green information technologies are regulated are defined by the International Organization for Standardization (ISO) 14000, which is an Environmental Management System. These authors also argue that this ISO is defined by the Environmental Management System (EMS), auditing, environmental labeling, and life cycle of the product.

According to Almeida and Real [11], the above-mentioned ISO is defined by several documents, as follows: SGA (ISO 14001 and ISO 14004), Environmental Audits (ISO 19011), Ecological Label (ISO 14020, 14021, 14024, 14025), Environmental Performance Assessment (ISO 14031 and 14032), Product Life Cycle (ISO 14040, 14041, 14042, 14043), and Terms and Definitions (ISO 14050).

However, it is valid to say that ISO 14000 is optional, despite the supporting documents. The argument for non-mandatory applicability of this regulatory standard is relating to the investment companies would have to make to adapt their production and products as “green”. This issue contributes to non-alignment with the ideal of sustainability.

In addition, the Brazilian laws directly related to the sustainability proposal are also discussed. It is worth mentioning Law No. 12,305, of August 2010, which provides guidelines for handling and disposal of solid waste, concerning environmental preservation and public health quality improvement. According to Cardozo and Murarolli,

> For Green Information Technology, specifically, Article 33 of this law deals with electronic waste, in which the companies themselves are responsible for the appropriate disposal of materials, in order to reduce the impact directly caused by them on the environment and human health. This Law describes in great detail the correct way of what to do with solid waste, thus becoming essential nowadays. [2]

In a dialogue with Smaal [12], Cardozo and Murarolli [2] explain that electronic waste does not refer to spam sent to e-mail boxes, but to waste produced from the obsolescence of electronic products. According to these authors, since the beginning of production until the disposal of the product, there is a high environmental impact. Thus, it is necessary to implement a project to reduce the production of these pollutants, whose environmental damage is incalculable.

These authors also mention that the government has a virtual platform, which was developed through an initiative by the Environment Department of the state of São Paulo (2008), in which the Zip Code of a municipality can be inserted to found out the nearest place for proper disposal of electronic waste. The website (www.e-lixo.org) is maintained by crossing data with Google Maps. They also emphasize the importance of the correct disposal of this kind of waste because it contains heavy metals, which can easily contaminate the soil and water, causing diseases to humans.

Cardozo and Murarolli [2] argue that the environmental management policies and the measures for relocating electronic wastes, correctly disposing them, recycling, and reinserting in the production chain what would be disposed in the environment, mean a new and important step in the environmental conservation and concept of sustainability. According to these authors, in dialogue with Baio [13], it is estimated that 5% of the waste generated by human beings on the planet is electronic, which corresponds to about 50 million tons per year. The appropriate disposal of this waste also means to collaborate to reduce this number.

In another way, but contemplating the topic of this section and the proposals on the need for the correct disposal and destination of solid waste, Santos *et al*. [3] address alternatives to make feasible the correct disposal of these residues. In addition to electronic waste, cited by the authors mentioned so far, the disposal of effluents in water resources is one of the major concerns regarding pollution.

According to Santos *et al*. [3], large cities are the main responsible for the disposal of waste in water resources and, consequently, for their pollution. Archela *et al*. [14] explain there are two types of disposed effluents, which differ from each other by their origin (domestic and industrial). Cooking oil is in the group of domestic waste, being an organic compound with a high contamination rate of water resources when disposed incorrectly. Santos *et al*. [3] argue that, according to the Environmental Management Program of the Federal Public Ministry, 1 L of cooking oil is enough to contaminate about 1 million L of water, which is enough to be consumed by one person for 14 years.

These authors claim there is still no exact data on the oil reused by industries, the one that returns to the production cycle. However, according to them, work has been done to raise the population’s awareness of its correct disposal, as this process does not require high investment, but only changes in habits.

Regarding the disposal of industrial waste, Santos *et al*. [3] explain that, in the state of São Paulo, control and inspection are strict, supported by Law 997/76, based on which, through environmental licensing and inspection of activities, companies are analyzed by the Environmental Company of the state of São Paulo (CETESB), a delegated body of the state government.

On a national scale, there is the CONAMA Federal Resolution (No. 430 of 2011), responsible for the classification of water bodies and environmental guidelines, establishing standards for the discharge of effluents. According to Santos *et al*. [3], for vegetable oils, there is a limit of 50 mg/L of effluent compounds.

Thus, based on these data, these authors are also concerned with defining the concept of Reverse Logistics, which is an important tool for controlling the flow and return of products and inputs to the means of production. Logistics is the “management of a duly structured and planned supply chain, involving the storage, transportation, and control of materials or products” [15].

They also argue that logistics contributes to improving efficiency in relation to the substantial gains of a company since the production flow occurs from the correct and necessary amount for the sale and return of the product.

According to Leite [16], there are four characteristics related to logistics: supply logistics, manufacturing support logistics, distribution logistics, and reverse logistics. Each one has its importance in the production cycle. The first characteristic is necessary for the supply of inputs and materials for the company's production; the second one for planning, storing, and controlling the company's internal flows; the third, for product distribution; and the last one for the return of post-sale and post-consumption products.

The discussion by Santos *et al*. [3] focuses on this last characteristic: reverse logistics. The post-sale reverse logistics is characterized by the return of products with quality problems and/or errors in their distributed quantities. The post-consumption reverse logistics is characterized by the return of the product after consumption by the customer, so that in some way it is reused, through reuse, manufacture, or recycling.

Cooking oil is an example of a product returned to the industry through post-consumption reverse logistics. This oil has a variety of uses such as for saponification, the composition of paints, production of putty, production of flour for animal feed, burning in a boiler for biodiesel production and consequent generation of glycerin as a final product, among other purposes, as pointed out by Reis, Ellwanger, and Fleck [17], cited by Santos *et al*. [3].

Therefore, in order to discuss the advantages of using Information Technology in the production process as a competitive differential, Santos *et al*. [3] define "Information Systems (IS)" as:

> [...] Interacting and interdependent parts of a set that form an organized whole, and aim to generate accurate and auxiliary knowledge regarding decision making, analysis, and transformation of information, generating value through the data presented in a meaningful and useful way. [3]

Thus, the use of IS in companies directly involves information technologies for the development of services, products, and capabilities so that they can develop competitiveness among other companies and on a global capital scale.

The management information systems (MIS) are an example of information technology used internally in the production process of a company. These systems contribute to organizing a sparse volume of data, which can be a big problem for controlling the flow and return of products, logistically, such as in the case of reverse logistics for cooking oil. The MIS are implemented as instrumental technologies in business intelligence (BI), giving the company a competitive advantage over others, when it comes to process optimization.

To exemplify the use of MIS in companies as a competitive advantage technology in the market, Santos *et al*. [3] cite a database structured to contain information on the collection of used vegetable oil (post-consumption) and its return to the production process – regardless of its later use.

To this end, the system's architecture, produced for this purpose, initially consisted of a form filled out by organizations that collect the residual oil from other companies, whether NGOs or other collection points. This form is later modified and supplies a database, which stores information in an analytical Data Mart, specifically for this context. Finally, the produced database is used to design reports, which will be green marketing instruments to structure the company's image as being environmentally responsible.

Thus, the initial form used by the initiatives, which were organized based on vegetable oil collection points, is filled out through a standardized interface, linked to a website, being a transactional database. In this way, important information is stored and used in a mapping of the entire reverse logistics process of this oil.

From the primary characteristics that structure this MIS, after filling out the initial form, information is screened by an Extract, Transform, and Load (ETL) system. In dialogue with Kimball and Ross [18], Santos *et al*. [3] explain that this system consists of three stages: "[...] a desktop, instantiated data structures, and a set of processes. This system deals with the systematization of treatment and cleaning of data from different organizational systems for insertion in a Data Mart".

Using some metrics obtained from this system, it is possible to create cartograms, for example, which will illustrate the company's ability to return residual oil and transform it into other products, which, as previously mentioned, is an instrument for increasing the company's green marketing, which also establishes a "healthy" sphere of competition among companies and, of course, emphasizes the value of reverse logistics of this oil.

Based on the MIS used as an example, Santos *et al*. [3] affirm the importance of this method, not only for the company's green marketing but also for socio-environmental responsibility. For this purpose, one of the franchises of the McDonald's fast-food chain (São Paulo), which uses an MIS for the reverse logistics of cooking oil, has been used as an example.

The results obtained from the database of oil collection and transformation showed that the aforementioned company collected about 6 million liters of oil in a year, thus preserving 150 billion liters of water. This means, according to the company's data, a number close to 12 thousand million m^3 of avoided CO_2 emission, which is equivalent to about 70 thousand trees planted. Moreover, almost 6 million liters of biodiesel can be produced from the return of this cooking oil post-consumption.

Based on the mentioned case study, the use of information technology applied as MIS in the control of reverse logistics proves to be an important tool, not only in the competitive advantage among companies but also in the partnership between these institutions, when environmental preservation and financial saving are a common interest in the production process.

4. Solid Waste and Green Patents

This section specifically addresses the solid waste issue in the Brazilian civil construction sector, from the perspective of Silva *et al*. [4]. This discussion is justified by the fact that civil construction produces more waste, per inhabitant, in comparison with domestic waste production, as argued by these authors.

As shown by Silva *et al*. [4], based on data from the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE), in 2014, the quantity of solid waste generated by civil construction was greater than that from domestic activities. It was estimated that each inhabitant produces 1.062 kg of domestic waste per day. Regarding civil construction waste, this number was estimated at 1.5–2.5 kg daily. These authors report that civil construction waste is divided into 63% mortar, 29% concrete and blocks, 7% other components, and 1% organic waste.

Silva *et al*. [4] argue, based on a dialogue with Magalhães [19], that innovation consists of any evolutionary or disruptive change aimed to prolong the life of organizations. In this sense, they claim that the civil construction sector in Brazil has a high ability to innovate and stimulate the economy, through recycling technological innovations, which, however, still lacks a long-term plan.

These authors explain that green patents are technologies focused on their goals of positively interfering with the environment to preserve it and prevent climate change and environmental degradation. They also argue that, in Brazil, the National Institute of Industrial Property (INPI) prioritizes the evaluation and approval of patents related to this purpose. According to the INPI (2013), mentioned by these authors:

> Within the scope of innovation that Green Patents can provide, technologies focused on the promotion of renewable energies, energy conservation, pollution control, reforestation techniques, soil improvement, waste disposal, waste treatment, and waste management stand out. [4]

Green patents in Brazil account for 5% of the total number of registered patents, and they are related to the "efficient processing of materials, composition, and process to obtain products that cause less damage to the environment, and waste recycling processes" [4].

Between 1991 and 2015, according to Silva *et al*. [4], 182 technology patents were registered, which were related to the reuse of solid wastes from the civil construction sector in Brazil, their recycling, and systems and processes towards sustainable practices; 168 of them were invention patents and 14 were utility models. According to these authors, the most significant periods regarding the increase in the number of registered green patents in Brazil were from 2002 to 2005 (an increase from 2 to 12 registrations) and from 2006 to 2009 (an increase from 9 to 21 registrations).

As for the profile of depositors responsible for registering patents, Silva *et al*. [4] report that 74% were natural persons and 26% were legal entities, of which 21 registrations were from Educational/Research

Institutions, 20 from private companies, and 7 registrations resulted from public-private partnerships. The other 134 registrations comprised patents registered by natural persons. Most of the patents registered by educational institutions and/or research centers, private companies, and public-private partnerships are found in the South and Southeast regions; only one was from northeastern Brazil.

According to Silva *et al*. [4], patent applications made to the INPI are classified according to the technological area to which they belong. They explain that 99 of the 182 patents found were classified, as follows: C04B (74 patents), E04C (14 patents), and B09B (11 patents). The other patents were classified into other categories.

The C04B comprises materials such as lime, magnesia, slag, cement and its compositions (mortar, concrete, or building materials). The E04C includes structural elements (construction materials). The B09B classification comprises the disposal of solid waste. In the authors' analysis, 56% of all registered green patents are concentrated in these three classifications.

The three studies that served as the basis for the theoretical review in this section show the lack of correct disposal of solid waste, in addition to a counterpoint through case studies, such as in the second text discussed here, evidencing that the applicability of green technologies to industries and other sectors of the economy results in mitigating and environmental preservation measures.

Another important fact is the advent of information technology and disruptive technology as methods to make feasible the recycling, reuse, and correct disposal of solid urban waste, so as not to degrade the environment, in addition to making possible financial saving and better management of costs in production processes.

5. Disruptive Technologies

Before specifically addressing disruptive technologies and their current behavior, it is necessary to understand how they emerged and what they are based on. To do so, it is necessary to understand the concept of innovation, which Schumpeter [20] *apud* Theis and Schreiber [7] defines as everything that expands, causing a change in the circumstances of economic equilibrium. According to this author, it is possible to cite, for example, the discovery of new forms of production and commercialization or the development of new products, services, and technologies.

Drucker [21], agreeing with Schumpeter [20], emphasizes that innovation is the main tool to awaken the entrepreneurial soul, with which it is possible to find utility for any element in nature capable of generating wealth. Thus, innovation consists of creating solutions for consumption, transforming any and all changes into a great business opportunity [7].

Therefore, applying technology or scientific knowledge to improve processes and products can be considered a major factor of competitiveness among companies, since they are important aspects regarding the consumption decision-making process [7].

The Oslo Manual, which is an important international guideline document on innovative activities in the industry, establishes four types of innovation, as follows: (1) product innovation, which is the development of a new technological product or service modified by technology; (2) process innovation, which alters and benefits the production process, even if there is no change in the final result of product or service; (3) marketing innovation, which corresponds to those changes made when a new product is launched on the market; and (4) organizational innovation, which are changes in the way of conducting processes in a company, as long as their results can be proven by improving productivity, in sales or profits, for example [22].

In this sense, based on these innovation concepts, the idea of disruptive innovation was also outlined, which is defined by Christensen [5], the main researcher on this topic, as the process in which a product or service enters the base of a market and starts to move to the top of this market until it occupies a position that reduces or completely eliminates competition.

For Christensen [5], disruptive innovation corresponds "to situations in which new companies can develop relatively simple, convenient, and low-cost innovations to promote growth and overcome the sector leaders". This model ensures greater accessibility for people who previously had no access to this market. This characteristic makes developing countries the best niches for launching this type of innovation.

This fact is due to the business model of these countries and the low-income population, following a logic that it is better to enter a market where there is no competition, as there is no consumption, rather than enter directly into global markets, in which there is already a habit of consuming this type of product/service. This system ends up benefiting the population with less purchasing power and has a high potential for growth [23].

Therefore, there is a disruption in the market when an innovation or technology replaces the product commonly appreciated by the public, even if it has lower performance, also reaching a portion of consumers more sensitive to price [9].

However, it is also essential to show how some technologies influence considerably in biopolitical aspects, being able to promote an increase in consumption by storing information in the databases of large companies. Through artificial intelligence techniques and algorithms, a consumption structure can be recreated and make advertising campaigns more accurate according to the target audience [24]. For this reason, one cannot ignore the direct relationship between consumerism and the disruptive technologies that feed it, also contributing to the intensification of calamity situations observed in the current ecological scenario [24].

Christensen [5] considers that disruptive innovation refers to all technological changes used to transform labor, materials, capital, and information into products and services with possibilities to add value [8]. Nevertheless, it is possible to perceive this principle of disruptive innovation in several spheres, not only in the institutional context of generating profits and economic advantages. In other words, disruptive technologies do not need to be practiced solely for commercial purposes [24].

Theis and Schreiber [7] point out that most environmental innovations are currently reactive and motivated by environmental regulations and laws, and cannot be sustained by the simple fact that they are not genuinely honest with the ecological principle. They simply seek to survive the market, respecting the impositions of the government or society.

Thus, it is questioned about the possibility of developing disruptive technologies with educational and awareness-raising goals, with a high capacity to modify their users' thoughts and consumption habits.

These tools could cause an imaginary disruption of high population impact, since they would be aimed at the masses, causing permanent changes in the consumers' subconscious. This is the case of the tools analyzed in the next section, which were developed to quantify the natural resources saved by recycling solid waste generated by consumption, thus making this reality more palpable in the consumers' subconscious.

6. Intelligent Garbage Can[2]

According to Christensen [5], disruptive technologies are those that provide different values in comparison with the main technologies, such as the intelligent garbage can, which aims to educate consumers about the amount of natural resources saved when waste is disposed for recycling.

This garbage can is a green patent because, as explained by Silva *et al*. [4], it aims to bring about positive changes for the environment by raising the population's awareness and improving solid waste recycling processes.

The intelligent garbage can[3] uses advanced technology to identify, collect, and process data from different types of recyclable materials. The machine has programming developed in C++, recorded in a PIC16F877A-I/P microcontroller to identify the collected waste, storing it in compartments ready for selective transport. When consumers dispose the waste into the can, they receive a coupon, informing them about the quantity of natural resources preserved by recycling that material.

The system is basically composed of 5 main blocks. First, the insertion of an object is detected, then the type of inserted material (PET bottle or aluminum can) is identified so that the anti-fraud test can be

[2]Patent: Privilege of Innovation. Registration No.: MU00251302795267. Title: "Intelligent Garbage Can". Registration institution: INPI - National Institute of Industrial Property. Deposited on April 4, 2013.
[3]More information about the Intelligent Garbage Can at: <https://www.youtube.com/watch?v=PzXHWIt6Dnw>.

performed. If the object does not pass the test, it is rejected, otherwise, it is compressed and then separated. The machine, according to its programming and volumetric capacity sensor[4], gives information about its filling every 20% and when it reaches 100%, a sign is sent to the server, which activates a siren through a Web system developed with the following sayings: “Trash with 20%”, “40%”, “60%”, “80%”, and “100%” (full garbage can) (Figures 3, 5 and 6).

When the garbage can is full, a team is activated to empty it and send the materials for recycling, in a reverse logistics process that, according to Santos *et al*. [3], is the return of the leftover product to the production chain, in this case, through recycling.

It is worth mentioning that, for each material discarded into the intelligent garbage can, identified data are sent to the server, using a GSM/GPRS communication protocol, i.e., a cell phone connection APN coupled to the can’s electronic circuit (Figure 5). The data sent to the server’s fixed IP are received by the Java Servlet socket and inserted in the Mysql database. Thus, the treatment of spatial information is shown in reports generated from each garbage can, developed in the PHP programming language. This resumes the idea of virtualization defended by Cardozo and Murarolli [2].

The reports contain the following information: quantity of product stored per type of recyclable material, the idle capacity of the machine, natural resources saved per consumer, or overall, geographic location of the machine (increasing its security). Any information is obtained in real-time when the system allocated in the domain <www.lixeirainteligente.com.br> is accessed.

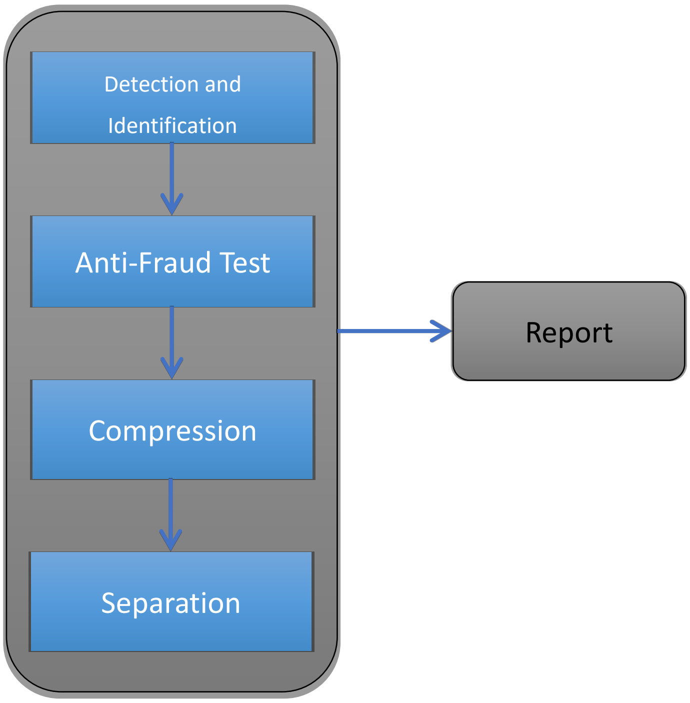

Figure 1. General System Block Diagram. Source: By the author (2020).

The electronic system is shown in Figure 2, in which the interference of the magnetic field is measured

[4]To measure the percentage of waste that occupies the can, we use an ultrasonic distance sensor, which measures the distance, according to the sound response time. The XL-MaxSonar-AE was used (see Figure 5).

for the object identification if it is made of aluminum. This is also a stage for the anti-fraud test. If the inserted object is a plastic bottle, it will be identified by a capacitive sensor. The weight is measured to verify if the bottle/can was disposed empty (or not) and it is also a variable for the classification algorithm, which, in the calibration process, will be used in several tests, interlinking the collected information to determine patterns.

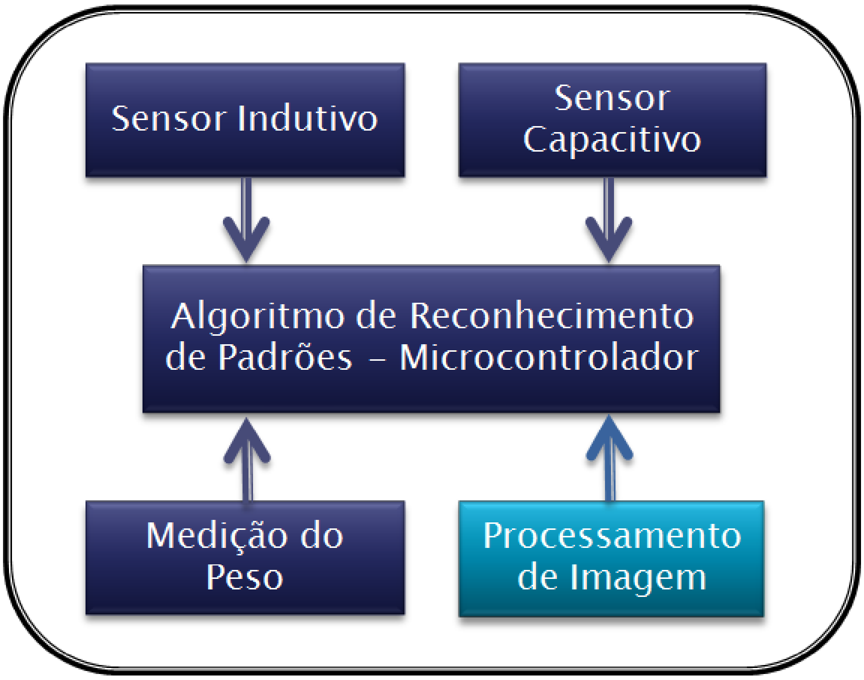

Figure 2. Block diagram of the Electronic Design Architecture. Source: By the author (2020)

The "decision tree"[5] is used as a classification method (Figure 5), which is an artificial intelligence system with a pattern recognition algorithm. This algorithm comprises the classes, which, in this case, are the different types of materials.

An Excel spreadsheet was also created to calculate the amount of resources saved from what is collected/recycled. When filling the spreadsheet with the amount of collected material in tons (e.g. aluminum, metal, paper, plastic, and glass.), the quantities of saved resources are immediately calculated and shown in another spreadsheet and in graphics (Figure 3).

However, the most interesting thing is how people relate to this disruptive technology. At first, they deposit their waste with some suspicion or without understanding the real dimension of that information in their lives, in their daily lives. Then, when they look at the coupon and realize the amount of energy saved by recycling that particular material, for example, the situation takes shape in their imagination and, even if they never use that garbage can again, every time they deposit waste in any can, they will

[5]The decision tree is a multi-stage decision system in which classes are sequentially rejected, until finding an acceptable class. In the end, the space of characteristics is divided into regions corresponding to the classes. The decision sequence is applied to individual characteristics, checking if a certain characteristic is above or below a certain threshold. Each decision node contains a test on an attribute, each descending branch corresponds to a possible value of this attribute, each leaf (represented by the rectangle) is associated with a class and each path in the tree (from root to leaf) corresponds to a classification rule.

remember the experience they had with the intelligent garbage can. It is as if what they learn from that information is permanently impregnated in their subconscious, thus causing a disruption, which occurs from this change of thought and attitude towards the garbage/waste.

The discussion on this type of disruptive technology, of green patent and with educational and non-profit goals, differs from that common academic discussion, which addresses disruptive technologies from the point of view of labor precarization such as in the case of drivers and deliverers who use mobility and food apps, respectively.

Through these innovations, it is intended to address the change in the look by the information, the ability to disseminate awareness-raising information, through very low-cost tools that can even generate a policy to include everyone in discussions on ecology, and education on environmental preservation and anthropogenic activities.

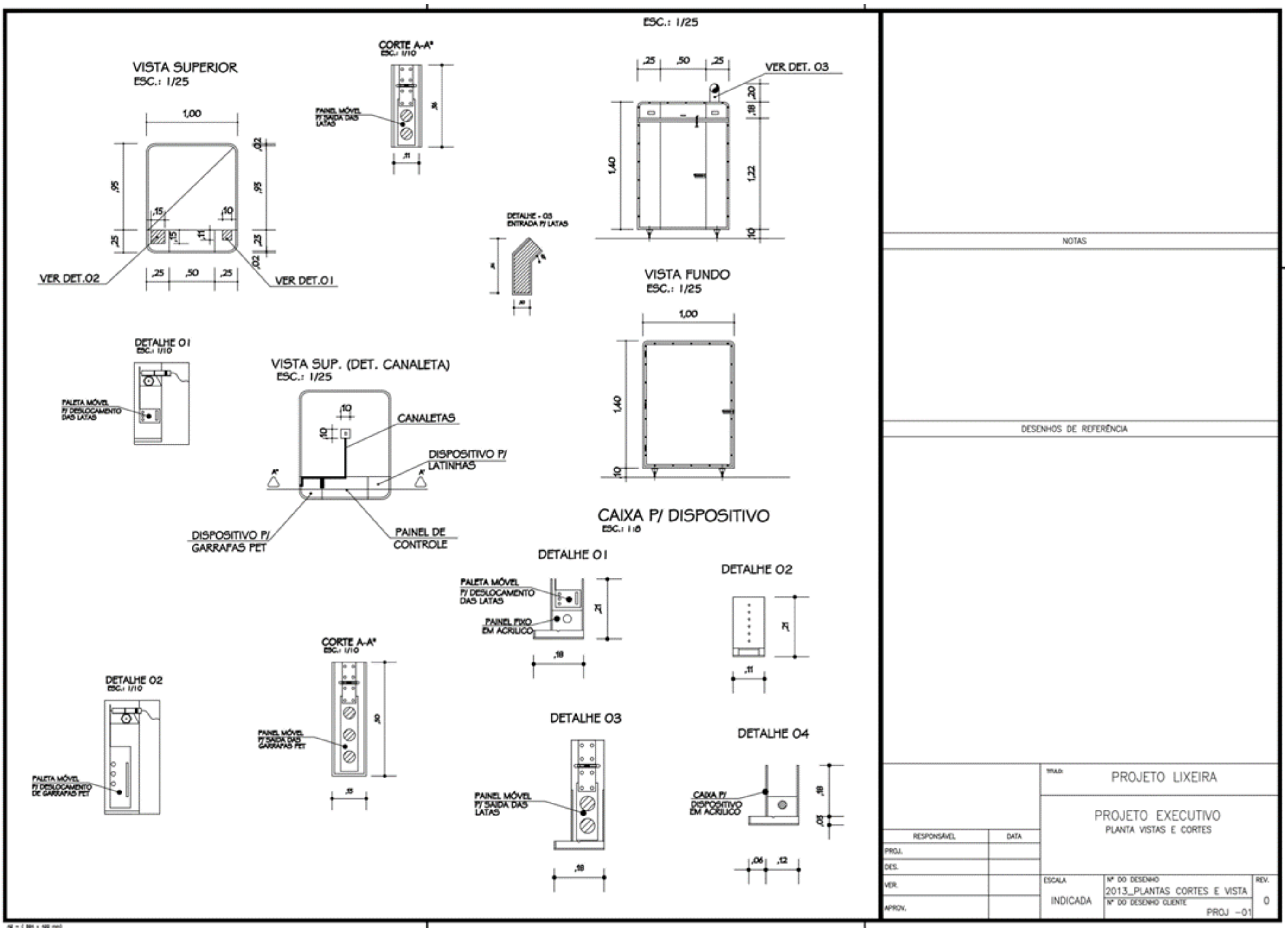

Figure 3. Intelligent garbage can: Section and Views. Source: By the author (2020).

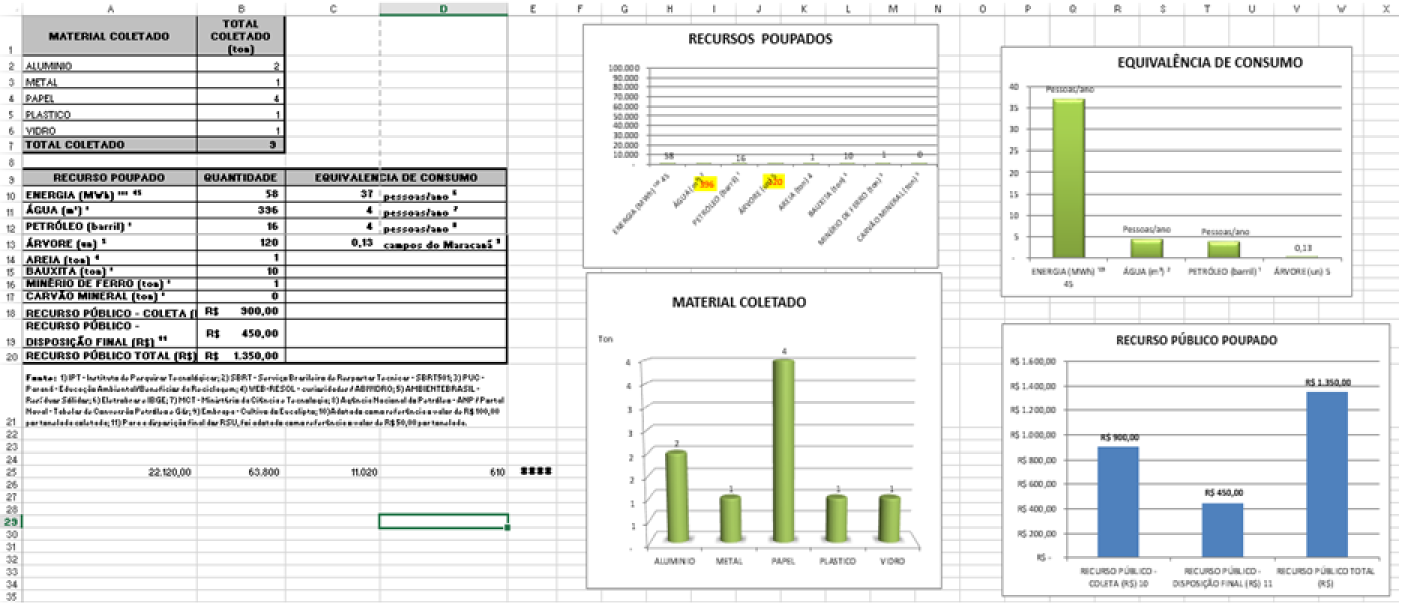

Figure 4. Natural resource calculator[6]. Source: By the author (2020).

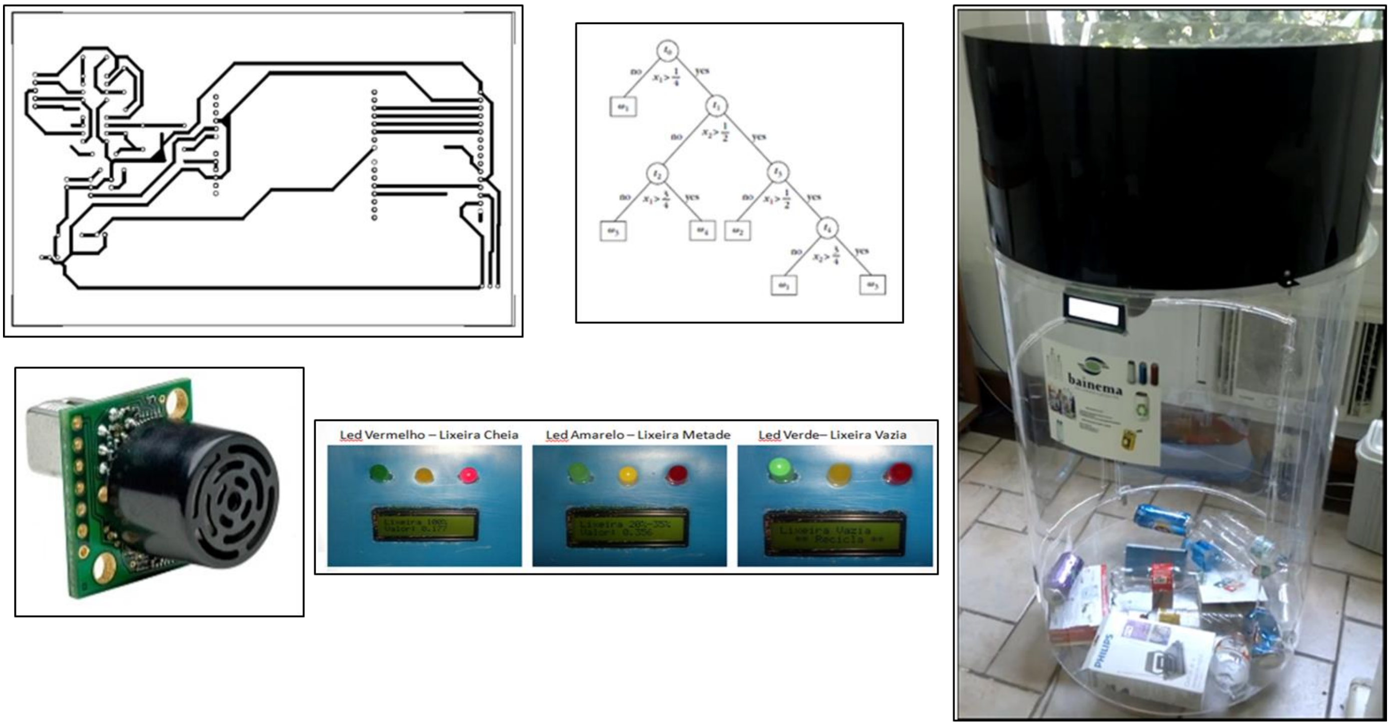

Figure 5. Intelligent garbage can: Printed electronic circuit board, 128x64 Graphic LCD Display, 40KHz Ultrasonic Sensor (RX and TX Pair), Decision Tree. Source: By the author (2020).

[6]Source: (1) IPT - Technological Research Institute; (2) SBRT - Brazilian Technical Response Service - SBRT501; (3) PUC - Paraná - Environmental Education/Benefits of Recycling; (4) WEB-RESOL - curiosities/ABIVIDRO; (5) AMBIENTEBRASIL - Solid Waste; (6) Eletrobrás and IBGE; (7) MCT - Ministry of Science and Technology; (8) National Petroleum Agency - ANP/Naval Portal - Oil and Gas Conversion Tables; (9) Embrapa - Eucalyptus Cultivation; (10)The amount of R$38.00 per ton was adopted as reference for the final disposal of USW. The calculations used by the author for developing the Intelligent Garbage Can were based on this source.

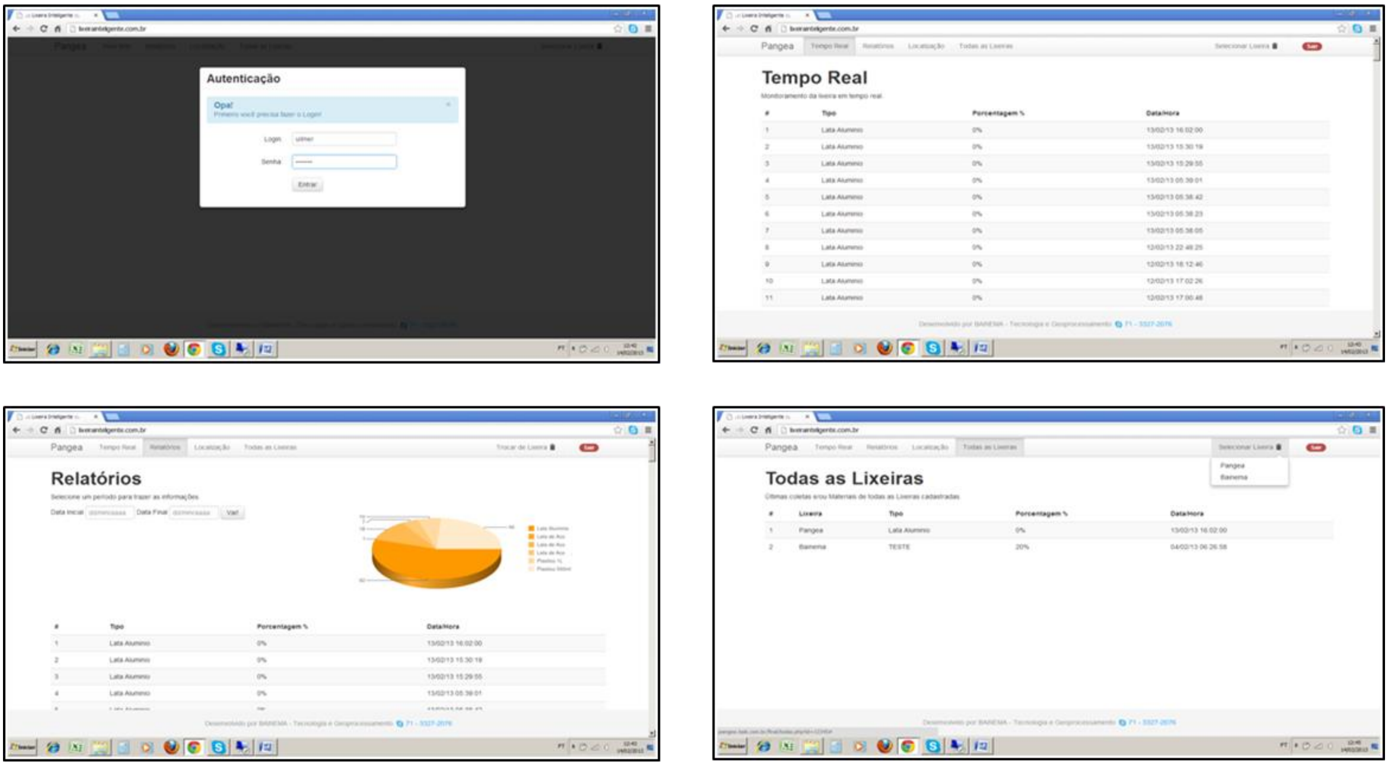

Figure 6. Web system: Intelligent garbage can. Source: By the author (2020).

7. Recycling Scoreboard[7]

The recycling scoreboard[8] was developed to record all recyclable materials collected during the Carnival held in São Paulo and Recife (Brazil), in 2020. Through this technology, the public knew what types and quantity of materials were collected, as well as the volume of natural resources saved with the appropriate final destination of these materials. This tool operates similarly to the intelligent garbage can, as it uses online management reports and the natural resources calculator. This also resumes the concept of virtualization by Cardozo and Murarolli [2], as the virtual environment represents reality. The difference is that the recycling scoreboard seeks to reach a higher number of people in less time, since it is seen in major events, such as Carnival, soccer games, World Cup, and Olympic Games, and can, therefore, be considered a disruptive technology tool for environmental awareness of high population impact.

The recycling scoreboard mainly aims to raise carnival revelers' awareness and, consequently, reach the other layers of civil society. The process comprises the following steps: (1) the recyclable material collected by collectors during the events is weighted; (2) the scale immediately makes a connection via a communication protocol and inserts the data into the MySQL database; and (3) the dynamic data are shown every weighing and in real-time on a video screen (4 m high and 3 m wide) (Figure 7), which shows data related to environmental preservation associated with the population's daily tasks, as shown in

[7]Computer Program. Registration No. BR512013000238-9. Registration date: June 20, 2012. Registration institution: INPI - National Institute of Industrial Property.
[8]More information about the Recycling Scoreboard at <https://youtu.be/fVE81fJAknY>, <https://youtu.be/MXHruRHK0As>, <https://youtu.be/sRqTJ55qss0>, <https://youtu.be/YWjdbEWlwp8>, <http://porumcarnavalsustentavel.com.br/>, <http://domeulixocuidoeu.com.br/carnaval/index.php>. The dynamic video watched by the public during the Recycling Scoreboard is available at <http://recado.eco.br/recife/meulixo/video.php?infodados=0>.

Table 1.

Table 1. Quantity of material and equivalent saved resources.

Collected Material	Quantity	Saved Resources
Aluminum cans	648,769	Energy Consumed by 71,169 people
Glass	2	Saves sand when building 0 (m^2) of popular houses.
PET - Plastic	3,099	Saves gasoline to run 4,927 Km.
Paper	1,503	Saves 67,635 liters of water
Total collected	13 tons of waste	Equivalent to 181,030 liters of water, so it saves an average of 302 hours of bathing.

Source: By the author (2020).

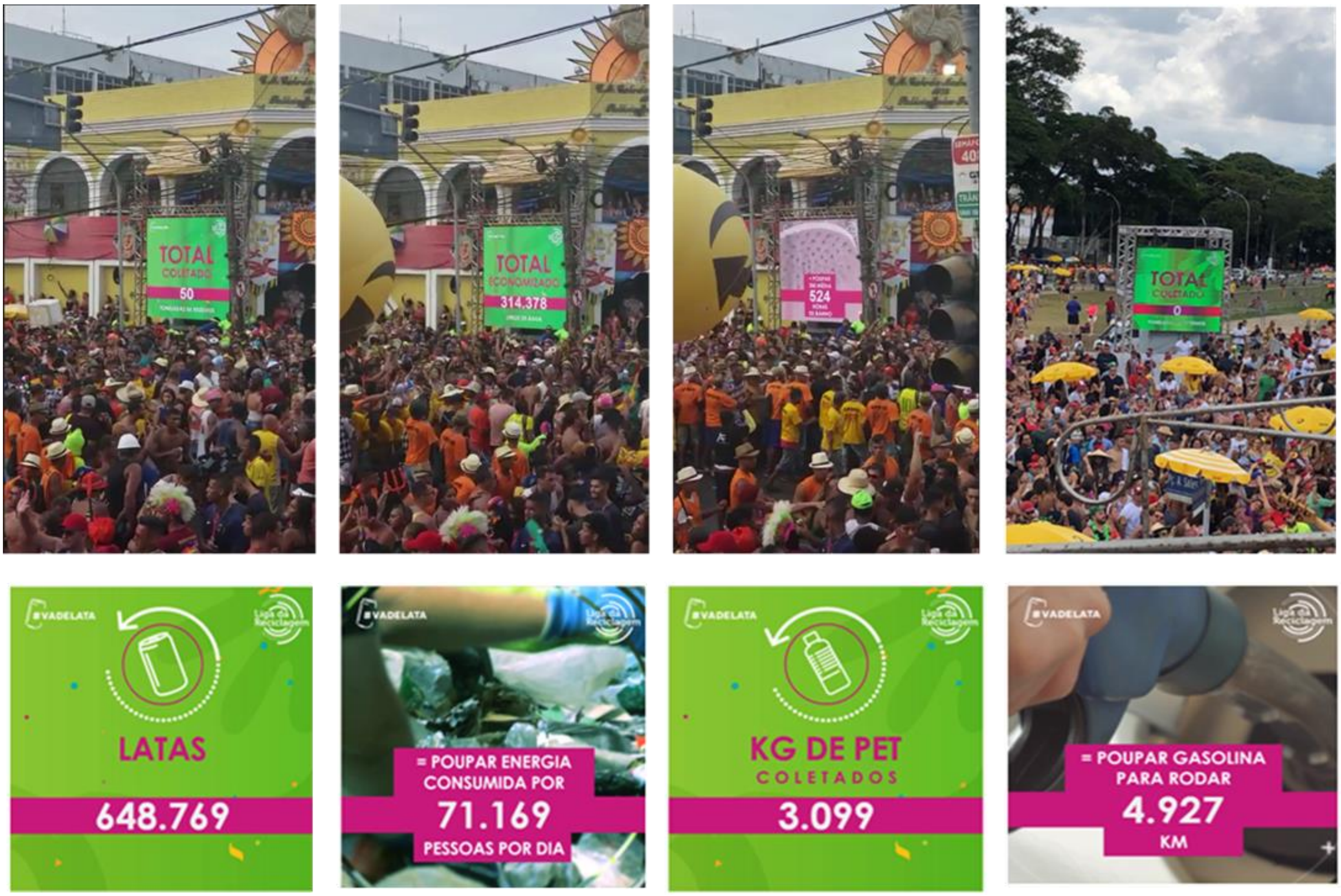

Figure 7. Video screen image of the Recycling Scoreboard. Source: By the author (2020).

The recycling scoreboard, from the perspective of meeting the legislation requirements, combined with socio-environmentally correct initiatives, reached around eighty thousand people in Recife, in the “Galo da Madrugada”, which is a party that concentrates nearly one hundred thousand people, per night of the parade, which leads to significant waste production.

It also directly reached 120 thousand people in São Paulo and, indirectly, it reached an incalculable number of people through the mass media, such as TV reports (Globo, Record, SBT, etc.), and news publicized on several websites.

The Carnival in Recife, particularly, had a different action promoted by the partnership between two companies (Ball and Novelis), which gave the event incentives and support, in compliance with what is determined by the National Solid Waste Policy – Law 12.305/2010 – PNRS:

> Art. 7 The objectives of the National Solid Waste Policy are:
> XII - integration of collectors of reusable and recyclable materials in actions involving shared responsibility for the products' life cycle;
> Art. 8 The instruments of the National Solid Waste Policy are, among others:
> - solid waste plans;
> III - selective collection, reverse logistics systems, and other tools related to the implementation of shared responsibility for the products' life cycle;
> IV – incentive for the creation and development of cooperatives or other forms of association of collectors of reusable and recyclable materials. [25]

The recycling scoreboard, combined with the precepts of the Sectoral Agreement, favored the participation of recyclable material collectors in the selective collection process, both in technical tests and in the "Samba" Schools parade days, ensuring environmentally correct actions for waste disposal, as well as job opportunities in the perspective of socio-productive inclusion for a significant number of waste collectors.

It is worth mentioning that the disruptive technologies considered in this article are related to the capitalist model of "environmentally sustainable" marketing; being, in this sense, aimed at the high population impact event frequent audience. The entrepreneurial modus operandi, which imaginatively suggests that the garbage collector dresses with personal protective equipment and high tax rates, can even feel "joy" during the exercise of their profession, hidden and silent in the daily reality of workers in cooperatives, streets and dumps. Exposed, therefore, a media service that "aggregates values, representations, ideas and guidelines on social reproduction services, guided by a competent ecological discourse dedicated to reproducing all the once 'only' ecologically correct world view". Del Gaudio [26].

The garbage collector, in these great events, escapes his dull and precarious daily life. This is because these events always take place in places belonging to the bourgeois ruling class, such as the Olympics, the World Cup, Carnival, Rock in Rio, Lollapalooza, etc. The recycling scoreboard, in this segment, appears to inform and change society's thoughts in relation to conventional dumps. However, in a critical analysis, the disruptive technologies shown in this article fulfill the function of "announcing a lot and silencing those who, in fact, made the decisions, made the choices, the discursive construction of this silencing through much saying, being silencing". Del Gaudio [26]. There is here a clear attempt to elucidate the environmental payment for the services provided at that time to society and to hide, historically, what was not paid in the day-to-day life of the Brazilian recycling network in which a domination strategy is carried out and it generates a very efficient “ideological smoke wall”, since the mainstream media is responsible for promoting it on their websites and open / closed channels.

Finally, it is concluded that, similarly to the intelligent garbage can, the recycling scoreboard can also be considered a disruptive technology due to its ability to cause and establish changes (disruptions) in the consumers’ thoughts, resulting in a new behavior in their everyday activities. This technology is also a green patent because it aims to preserve the environment through innovation [4].

Moreover, it is worth mentioning the social issue, which leads to a paradigm shift in the waste collectors’ lives and in the way people see them, realizing how their work is important and valuable to society and the environment.

8. Conclusion

It is undeniable how much technology has occupied considerable space in people’s lives in recent decades. This is the result of large-scale industrialization caused by capitalism, which consequently increased consumption and the amount of waste, leading to routine discussions about ecology and sustainability. Inevitably, one thing leads to another.

In this sense, why not think about technology as an ally in the practice of sustainable development? How can it facilitate and improve people’s lives and care for the environment, at the same time? These are fundamental discussions nowadays because, despite the advantages of technologies and globalization, there are also disadvantages due to the overuse or misuse of natural resources.

Thus, it was observed in this study that sustainability is the balance between social, economic, and environmental factors. For this reason, Green Information Technologies are such a promising market, as they allow companies to combine innovations, financial, and ecological interests. This can be exemplified by the database information storage in VPS or “clouds”, making almost all transactions and processes virtual.

The resolutions and patents related to the disposal of industrial waste and civil construction solid waste were also addressed.

Furthermore, it was possible to understand the concept of disruptive innovations, coined and considered by Christensen [5] as all technological changes/disruptions aimed at transforming products, services, information, etc. However, this idea of disruptive innovation can be seen in several spheres, or rather, it does not need to be practiced solely for commercial purposes.

Therefore, two tools were presented here – the Intelligent Garbage Can and the Recycling Scoreboard –

which can cause an imaginary disruption of high population impact, since they aim at the masses, causing permanent changes in the consumers' subconscious. They were developed to quantify the natural resources saved by recycling solid waste generated by consumption, making this reality more palpable for the consumer.

Finally, given the above, it is concluded that information technologies have the potential to significantly contribute to the fight in favor of the environment, both through changes and disruptions in the way companies operate in the market, even if these changes aim at financial returns, and through applications or systems with educational and awareness-raising functions.

Thus, it is emphasized the importance of studies focused on the behavior of technologies faced with contemporary issues such as sustainability and environmental preservation. Technology must continue to be seen as having a facilitating role in the process of overcoming and solving problems, which are often also the result of modernity and globalization.

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